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SUBJECT: Interfaces Between AAP Experiments D008, S061, and SQ71/Q72 and the Communications System of the AAP CSM's - Case 620

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ABSTRACT

The interfaces between Experiments D008, Radiation in Spacecraft, S071/072, Circadian Rhythm-Pocket Mice/Vinegar Gnat, and S061, Potato Respiration, and the communications system of the appropriate Command and Service Module (CSM) of the Apollo Applications Program (AAP) are described. Use of one of the S-band power amplifiers of the Unified S-Band (USB) system of the appropriate CSM will be required whenever stored data from Experiment D008 is transmitted to stations of the Manned Space Flight Network (MSFN) because the S-band FM transmitter is used to transmit data from Experiment D008 which has been stored in the Data Storage Equipment (DSE) of the CSM. Whenever the S-band FM transmitter of the CSM is used, an S-band power amplifier will automatically be activated to amplify the output signal from the S-band FM transmitter before this signal can be routed to the CSM S-band antenna system. It is shown, however, that use of one of the S-band power amplifiers of the appropriate CSM's will not be required whenever stored data from Experiments S071/072 and S061 is transmitted to stations of the MSFN if transmission of this stored data is delayed until the CSM is sufficiently above the local horizon of a station of the MSFN. Determination of the minimum elevation angle from the MSFN station to the CSM (or maximum slant range) at which successful transmission of stored data from Experiments S071/072 or S061 can be achieved without use of one of the CSM S-band amplifiers must await completion of the measurement of the radiation patterns of the S-band antennas of the CSM when the CSM is docked to the Saturn V Workshop.

MEMORANDUM FOR FILE

Of the experiments currently assigned to the various Command and Service Modules (CSM's) for the defined missions of the Apollo Applications Program (AAP), only three experiments will have a significant interface with the communications system of the appropriate CSM. These experiments are: (a) Experiment D008, Radiation in Spacecraft, which will be conducted in the CM of mission AAP-2, (b) Experiments S071/072, Circadian Rhythm - Pocket Mice/Vinegar Gnat, which will be conducted in the SM of mission AAP-3, and (c) Experiment S061, Potato Respiration, which will be conducted in the CM of mission AAP-4. The interfaces between these experiments and the communications system of the applicable CSM are described in the following paragraphs. Some concern has been expressed by the Director, Apollo Applications Program, about the potential requirement for use of one of the S-band power amplifiers of the CSM whenever data from Experiments S071/072 is transmitted to stations of the Manned Space Flight Network (MSFN) via the Unified S-Band (USB) system of the CSM. Required use of a CSM S-band power amplifier as it applies to the support of each of these experiments is also discussed in the following paragraphs.

Experiment D008 - Radiation in Spacecraft

Since Experiment D008 will not be provided with the necessary data transmission or data storage capabilities to enable retrieval of pertinent data from the active dosimeter included in the experiment, it is planned to use the PCM telemetry and data storage systems of the CSM 116 (Mission AAP-2) to support the data retrieval requirements of the active dosimeter of Experiment D008. The minimum duty cycle for Experiment D008 consists of six continuous 45 minute periods per day for 14 days. The data output of the active dosimeter will consists of 9 simultaneous low frequency analog signals which will each be conditioned to extend from 0 to 5 volts DC full scale to be compatible with the PCM telemetry system of the CSM. These 9 analog signals will be routed to 9 one sample per second analog channel inputs to the CSM PCM telemetry system. These 9 analog

channels will be sampled once per second regardless of which one of the two built-in sampling programs in the PCM telemetry system is selected by a crewman or the Earth via the up-data system of the CSM. The two sampling programs will provide an output PCM data rate of 1.6 kilobits per second (kbps) and 51.2 kbps, respectively. It is currently planned to use the low bit rate sampling program in the PCM telemetry system during Mission AAP-2 except during periodic in-flight checkouts of CSM systems. Voice annotations by the crew during the conduct of this experiment may also be required.

Since sufficient line-of-sight contact time between the USB stations of the MSFN and the CSM during Mission AAP-2 will not be provided to meet the data retrieval requirements of Experiment D008 by transmitting the data in real-time, it is planned to route the 1.6 kbps PCM bit stream output of the PCM telemetry system, as well as appropriate voice signals, to the data storage equipment (DSE) of the CSM for recording during those periods of the mission when Experiment D008 is being conducted and the CSM and the appropriate stations of the MSFN are not within line-of-sight. The DSE includes a tape recorder which will be capable of recording simultaneously a voice signal and a low bit rate PCM telemetry signal correlated with a timing signal. The tape recorder will be capable of parallel playback of the recorded voice signal and the recorded low bit rate PCM telemetry signal with a tape speed 32 times faster than the record speed. The capacity of the tape recorder will be two hours of recording at the tape speed (3.75 inches per second) automatically selected when recording a 1.6 kbps PCM telemetry signal. It should be noted that the tape recorder has the capability to store the high bit rate (51.2 kbps) PCM telemetry signal instead of the low bit rate PCM telemetry signal. However, the capacity of the tape recorder will be reduced to one-half hour because of the required increase in tape speed to 15 inches per second (ips) and the playback tape speed of the tape recorder will be constrained to 15 ips. Hence, it can be seen from the capabilities of the tape recorder of the DSE and from the data retrieval requirements of Experiment D008 that only low bit rate PCM telemetry signal should be recorded, that data from Experiment D008 must appear in the 1.6 kbps PCM telemetry signal, and that the tape recorder must be dumped at least 3 times per day during those days when the experiment is in operation.

During the playback mode of operation of the DSE, the dumped voice signal and the dumped PCM telemetry signal will be routed to the premodulation processor (PMP) where a composite signal will be formed consisting of the dumped voice signal at baseband and a 1.024 MHz subcarrier phase modulated by the dumped PCM telemetry signal. This composite signal will be used to

frequency modulate the S-band FM transmitter of the CSM USB system. Whenever the S-band FM transmitter is operating, an S-band power amplifier will automatically be used and the high output power mode of operation of the power amplifier will be automatically selected. There are no other options available for use of the power amplifier when the S-band FM transmitter is operating and transmission of information dumped from the DSE can only be accomplished via the S-band FM transmitter.

Experiments S071/072 - Circadian Rhythm

The hardware for Experiments S071/072 includes a data system with the capabilities for collecting, processing, and storing data pertinent to these two experiments. This data system will collect analog and digital data from these two experiments, will digitally encode the data, and will store the data with a time reference in a core memory. The core memory will have a capacity sufficient to store data from these experiments for a period of 8 hours. This corresponds to a storage capacity of the order of 16,000 bits. In order that no data from these experiments be lost, the contents of the core memory must be dumped at least once every 8 hours. It should be noted that the planned duration of the experiment is 30 continuous days.

Since no provisions will be included in CSM 117 (Mission AAP-3) for storing the data dumped from the core memory of the data system of Experiments S071/072 for eventual return to the Earth with the CM after completion of mission AAP-3, it is planned to use the PCM telemetry system and the USB system of the CSM to transfer the data dumped from the core memory to any USB station of the MSFN. Obviously, line-of-sight between the CSM and a USB station of the MSFN must exist before data can be dumped from Experiments S071/072 and, as a result, data dump from Experiments S071/072 may occur more frequently than once every 8 hours to ensure that no experiment data is lost.

Control of Experiments S071/072 will be accomplished via the up-data system of the CSM or manually by a crewman from a control panel located in the CM in a back-up mode. Three set/reset commands will be provided; namely, (a) initiate, (b) dump stored data, and (c) transmit data collected in real-time.

Upon command, the data stored in the core memory or the data generated in real-time will be routed to the PCM telemetry system of the CSM. The data output from the core memory of Experiments S071/072 will consist of 24 bits of digital parallel data which will be presented to the PCM telemetry

system on 24 separate wires (with 3 data return wires). These
wires will also be used for transmission of experiment data in
real-time. The 24 data wires will be routed to three 8-bit
digital parallel input channels to the CSM PCM telemetry system
which will be sampled successively by the sampling program and
will appear in adjacent time slots in the output PCM bit stream.
In order that the core memory loaded to its full capacity could
be dumped during an average duration pass over a single MSFN
station, it is planned to use digital parallel channels in the
PCM telemetry system which are sampled 10 times per second and
to present each group of 24-bits of parallel digital data to the
PCM telemetry system for sampling for a duration somewhat
greater than 100 milliseconds. At this dump rate, the core
memory will have been dumped within 70 seconds. Only the high
bit rate sampling program, which results in an output PCM bit
stream of 51.2, kbps has sufficient digital channels available
to accommodate the data dump requirements of Experiments
S071/072 as now configured. It is currently planned to use the
low bit rate (1.6 kbps) sampling program in the PCM telemetry
system of the CSM during Mission AAP-3 except during periodic
in-flight checkouts of CSM systems and during dump of Experiment
S071/072 data. The 1.6 kbps or 51.2 kbps PCM bit stream output
from the PCM telemetry system will be routed to the PMP where it
will phase modulate a 1.024 MHz subcarrier which will in turn
phase modulate the transmitted carrier of the USB PM transponder
of the CSM. When the PM transponder is used, the S-band power
amplifier may be bypassed, be used in a low power output mode,
or be used in high power output mode.

    Performance margin calculations[1] on the S-band PM
communications link from the CSM to a USB station for a number
of different combinations of services (voice, ranging, and high
or low bit rate telemetry) show that the performance margins
will be positive for all services in any available combination
at a slant range of 1400 nautical miles without resorting to the
use of the S-band power amplifier except for high bit rate
(51.2 kbps) telemetry when transmitted simultaneously with voice
communications and ranging. As a result, the telemetry bit error
rate will be degraded from the arbitrary requirement of 10^{-6} to
10^{-5} which is more than sufficient for most applications. It
was assumed for these calculations that through selection of the
proper one of the four S-band antennas on the CSM a truly omni-
directional (0dB gain) antenna radiation pattern could be
achieved. Although this is a valid assumption when discussing
CSM missions in the Apollo Program, the validity of this
assumption for CSM missions in AAP will depend upon the results
of S-band antenna radiation pattern measurements on the CSM

when docked to the Saturn Workshop (SWS) which will not be available before the end of May, 1970. Intuitively, it appears likely that the antenna radiation patterns of the CSM S-band antennas will be adversely affected by the presence of the SWS resulting in a reduction of the performance margins on the CSM/MSFN communication links.

The maximum communications range of 1400 nautical miles used in the performance margin calculations slightly exceeds the slant range from a station of the MSFN to the CSM at the horizon when the CSM is in a circular Earth orbit with an altitude of 235 nautical miles. As noted earlier, in the current configuration of Experiments S071/072, it will take approximately 70 seconds to dump the contents of the memory core stored over a period of 8 hours of experiment operation. Hence, because the line-of-sight contact time for an average station pass will exceed 5 minutes, it will not be necessary to initiate the dump of the data stored in the memory core when the CSM appears on the horizon of the MSFN stations. For instance, if initiation of data dump from Experiments S071/072 and the corresponding switch from the transmission of low bit rate (1.6 kbps) telemetry to high bit rate telemetry to the MSFN station is delayed until the CSM is at least 15 degrees above the local horizon of the MSFN station, the maximum communications range will not exceed 700 nautical miles. At this range, high bit rate telemetry transmission to an MSFN station in any available combination with other services via the S-band PM communications link will have positive performance margins without using the S-band power amplifier on-board the CSM. These positive performance margins could then be used to help offset any CSM antenna radiation patterns degradation caused by the proximity of the SWS.

If this operational constraint is unacceptable to avoid a requirement for use of the S-band power amplifier during dump of data from Experiments S071/072, it appears possible to include the data dump from Experiments S071/072 in the low bit rate telemetry output from the CSM PCM telemetry system providing changes are made to the data system of Experiments S071/072. Referring to Appendix G, "Flight Operational AAP Measurement Requirements," contained in Specification Change Notice 361-G1 to document SID65-1642B prepared for use in the AAP CSM Preliminary Design Review held in October, 1969, it is shown that a number of digital channels (approximately 170) sampled once per second and a number of analog channels are available as spares in the low bit rate sampling program for CSM 117 as well as CSM's 118 and 119. It would be possible to use a number of these spare digital channels (at least 50 required to ensure

that complete data dump can be accomplished during an average station pass) to support the dump of data from Experiments S071/072. However, additional wiring would be required between the experiment package located in the SM and the CSM PCM telemetry system equipment and the data dump circuitry of the data system of Experiments S071/072 would have to be modified to provide the required increase in the number of output parallel digital channels and to change the rate at which the stored bits are dumped.

Alternatively, it would be possible to use a number of the spare analog channels in the low bit rate sampling program to support the data dump from Experiments S071/072. For this case, digital-to-analog conversion would be required for each group of 8 parallel bits. The resulting analog signal level would be routed to the PCM telemetry system of the CSM and this value of the signal level would be maintained constant for a period somewhat greater than one second for sampling. To ensure that the data dump can be completed during an average station pass, at least 6 analog channels must be used. Consequently, the data dump circuitry of the data system of Experiments S071/072 would have to be modified to provide the required increase in the number of output parallel digital channels (at least 48 bits), and to change the rate at which the bits are dumped, a digital-to-analog converter and hold circuit would be requried for each group of 8-bits (at least 6), and a change in the wiring between the experiment package located in the SM and CSM PCM telemetry system would be required.

It is the opinion of the writer that neither of the two alternatives described above to eliminate the operational constraint on the dump of data from Experiments S071/072 without resorting to use of an S-band power amplifier could be justified in terms of cost for the necessary modifications. However, assessment of the true magnitude of this operational constraint on the transmission of high bit rate telemetry must await completion of the measurement of the radiation patterns of the S-band antennas of the CSM when the CSM is docked to the SWS.

Experiment S061 - Potato Respiration

A self-contained data system will be provided in Experiment S061 to collect data pertinent to the experiment, to process and digitize the collected data, and to store the digitized data in storage registers. The storage unit will have a capacity sufficient to store data collected from this experiment during 250 minutes of continuous operation. Consequently, the storage unit must be dumped at least once every 250 minutes in order to avoid loss of any experiment data. Only

two parameters will be monitored by the data system and these parameters will be sampled once per minute. The voltage values of the samples will be digitized and stored in the storage unit. It is planned to operate this experiment throughout Mission AAP-4.

The same method used to transfer stored data from Experiments S071/072 in CSM 117 to the Earth will be used to transfer stored data from Experiment S061 in CSM 118 (Mission AAP-4). Upon command via the up-data system of the CSM, the data in the storage unit of the data system of Experiment S061 will be routed to the PCM telemetry system of the CSM. The interface between the PCM telemetry system and Experiment S061 will consist of 24 wires for digital parallel data and three data return wires, one data return wire for a group of 8 digital data wires. The 24 data wires will be routed to three 8-bit digital parallel input channels to the CSM PCM telemetry system which will be sampled successively by the high bit rate sampling program at a rate of 10 samples per second and will appear in adjacent time slots in the output 51.2 kbps PCM bit stream. These channels will not be sampled if the low bit rate sampling program has been selected for use in the PCM telemetry system. Each group of 24-bits of parallel digital data will be presented and held for sampling for a duration somewhat greater than 100 milliseconds. The stored data will be recirculated through the storage unit and will be dumped twice before the storage unit will be erased. Under these conditions, the data dump from Experiment S061 will be completed in approximately 40 seconds.

The discussions in the previous section on Experiments S071/072 and CSM 117 regarding the use of an S-band power amplifier during transmission of the dumped experiment data including alternatives to the current design also apply to Experiment S061 and CSM 118. However, because of the lesser amount of data contained in the storage units of Experiment S061 than in the memory core of Experiments S071/072, no increase in the number of output parallel digital channels will be required from Experiment S061 to ensure that the data dump can be completed during an average station pass.

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